RESEARCH IN FARM STRUCTURES, 1928*

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The work in farm structures during 1928 was of rather limited extent, especially at the agricultural experiment stations, and in some cases did not appear to be of particularly profound character. No recent record is available of the total number of structures projects in operation at the stations during the year, but it may be assumed that it was somewhere near the same as during the previous year, or about 40. It is significant to note that the record shows only two projects in farm structures operating on the Purnell fund during the year, one dealing with apple storages and the other with the development of a method of testing the members of farm structures. In addition, three Adams fund projects and three Purnell fund projects were in operation in plant physiology and horticultural departments which involved features of the storage of fruit, potatoes, sweet potatoes, and other vegetables. Some work was done in farm structures by agencies other than the agricultural experiment stations during the year, special attention being devoted to materials used in construction.

Some important work was done during the year and, while a complete review of it cannot be made here, attention is drawn to some of the more outstanding features.

POULTRY STRUCTURES

Some work was done on poultry structures which dealt primarily with ventilation and temperature requirements. The study at the Iowa Experiment Station of the air requirements of poultry showed that air purity is in itself of secondary importance. Temperature extremes and particularly rapid temperature fluctuations have an almost immediate effect in reduced production. Excessive relative humidity, while not desirable, does not produce detrimental results when the temperature is moderate and fairly constant. In this connection an automatic temperature regulator was developed for use in studies of the air and temperature requirements of poultry under fully controlled conditions.

Studies at the Indiana Experiment Station of the effect of artificial heat and insulation upon temperature, relative humidity, and air movements in poultry houses showed that there was little difference in the egg production in pens variously arranged. Where the temperature was maintained above 40° F. the relative humidity was 10 to 20 per cent lower than where no artificial heat or insulation was used. The litter remained drier and the birds appeared to be more comfortable, but the condition was not reflected in an increased egg production.

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The progress results of studies at the Nebraska Experiment Station indicated that the addition of neither a small house fan nor an exhaust fan to the ventilation system of a poultry house resulted in an increased egg production. There was a general falling off of egg production in all houses during extremely cold weather and only a slight increase where houses were artificially heated, although the egg production in the heated units was consistently higher throughout than in the unheated units. It appeared that the slightly increased production in heated units would not pay for the heating equipment and the heat. Apparently the value of commercial ventilators was not proven. In general large egg production seems to go with small temperature fluctuations.

Observations all over the country indicate that the housing of poultry to provide conditions for maximum economic production is presenting quite a problem. The above typical results suggest that air purity in a poultry house is not so important a factor in the health and productiveness of poultry as are temperature regulation and rates of air movement. A coordinated attack on this problem by the forces of poultry husbandry, animal pathology, and agricultural engineering would appear to be a logical undertaking, with particular reference to the establishment of housing requirements for definite sets of conditions. The importance of an adequate control technique has already been demonstrated at the Iowa Experiment Station, and the provision and manipulation of this appear to be logical functions of the agricultural engineers.

ANIMAL SHELTERS

There is now a great deal of evidence available that housing conditions are important factors in the profitableness of the animal and dairy industries.

The necessity for ultimate economy as well as efficiency in barn design and construction is reflected in the work on masonry arch barns which has been in progress at the Iowa Experiment Station for several years. The recent results show that under favorable conditions the cost of such a structure will be only from 25 to 50 per cent more than that of wooden construction. Efforts at waterproofing the roof have indicated the value and economy of treatment with raw linseed oil.

The necessity for a more profound consideration of the requirements of efficiency and economy in dairy husbandry practices is also reflected in the study conducted at the University of Wisconsin on the planning of dairy barns from a manufacturing point of view. This study showed that the average of 100 barns provided 50 per cent of the floor space for the convenience of the man doing chores. The total route distance per cow required for feeding hay, silage, and grain, and the operations of milking and manure removal was in favor of the face-in arrangement of stalls. The route distance per cow is nearly 19 per cent greater for the crosswise arrangement than for the lengthwise arrangement.

The importance of considering sanitation and cow comfort, as well as durability and economy, is brought out in the studies of dairy barn floors at the Iowa and Kansas Experiment Stations. The recent results at the former station indi-

cated that concrete and rubber block floors showed much the least wear of a number of types tested. While wood block did not show much wear it was not particularly sanitary. At the latter station particular attention was paid to the temperatures of floors of different materials during winter weather. In this respect solid concrete floors were found to compare favorably with floors constructed of building tile between two layers of concrete. A two-inch plank floor warmed up three to four times as rapidly as the concrete. Cork brick or creosoted pine block maintained about the same temperature as the plank floor and the creosoted block compared favorably with the cork brick.

Dairy stable ventilation is also still recognized as an important unsolved problem. The New York Cornell Experiment Station, for example, has demonstrated the economy and usefulness of natural draft ventilation for dairy stables, and in studies have established that the location of the outtake flues has a completely negligible effect on the convection currents of the stable air. It is therefore not necessary to provide a number of outtakes to insure uniform stable conditions. This means that one large outtake flue may be used for stables of at least 50-cow capacity and probably for more. The findings so far indicate however that the problem of designing intake passages is far from being solved.

The above typical results are from agricultural engineering studies receiving their impetus from definite agricultural requirements. It thus seems likely that a closer coordination of the forces of dairy and animal husbandry and agricultural engineering, to more clearly develop the requirements to be met in animal shelters for economical, maximum quality production, will materially strengthen the important work of developing materials and structural equipment which will provide the corresponding conditions.

It is interesting to note in this connection that considerable research work on structural equipment is being done by agencies other than agricultural engineering, the results of which might be effectively correlated with the requirements of animal shelters provided the latter were fully known. For example, the air permeability of structures, which is so important in the ventilation and temperature regulation of animal shelters, has received special attention. The Technical Academy of Munich has found in studies of walls that from the ventilation standpoint air renewal through walls is inadequate, especially when they are plastered. However, it was found that air movement through walls is very important in temperature regulation. The greatest passage of air through a brick wall was found to be through the mortar bond, and plaster coatings on brick walls have a lower air permeability than the walls. This is still further decreased by whitewashing. The resistance of plastered wood walls to air penetration was found to compare well with that of plastered brick walls. The University of Wisconsin found further that the same grade of workmanship results in more leakage through cement-lime mortar joints in a porous brick wall than in a hard brick wall.

As regards heat losses through walls the Building Research Board of Great Britain found that the phenomenon of heat transmission through a hollow wall is complicated by the convection currents set up in the interspace, the magnitude

of which is dependent on the position of the wall and the dimensions of the interspace. It was also found that the heat transmission through a hollow wall can be computed from a knowledge of the conductivity of a solid wall of the material and data on the thermal transfer between two vertical hot and cold surfaces.

In this connection the American Society of Heating and Ventilating Engineers found the coefficient of total heat transmission to be 0.16 for a brick-hollow-tile wall, 0.295 for insulated steel deck roof, 0.29 for a 12-inch hollow-concrete-block wall, and 0.17 for a brick veneer wall. The Colorado Experiment Station also reported that a much greater efficiency is obtained by using two one-half-inch thicknesses of insulating material separated by an air space in place of a one-inch thickness of the same material.

CROP STORAGES

The problematic nature of the situation regarding fruit and vegetable storage on farms is reflected in the fact that storage practice now usually allows for a certain percentage of loss in the stored products. Recent research findings also indicate a certain perhaps invisible but nevertheless appreciable amount of nutritive and culinary deterioration in certain fruits and vegetables which have been stored for various periods under different conditions.

The practice in the past has often been to simply build a storage structure and, in the interest of economy, to store several different types of fruits and vegetables therein, maintaining the best storage conditions for the more important commodities so far as possible.

However, the findings of plant physiologists and pathologists, horticulturists, and nutrition chemists during recent years have thrown considerable light on this situation. For example, the Maryland Experiment Station has found the potato to be a somewhat temperamental commodity in storage. Considered from the standpoint of the abnormally high respiration rate when removed from cold storage, 40° F. appears to be the best storage temperature for potatoes. The respiration rate in potatoes moved from 40° F. to market temperatures was high but it was not half as high as in potatoes removed from 36° F. storage. On the other hand the U. S. Department of Agriculture reported that carrots stored at 39-40° F. lost about 26 per cent of their weight and those stored at 32-35° F. only 7 per cent. These results would suggest that potatoes and carrots may not do well under the same storage conditions.

The Cawthorn Institute of New Zealand found that considerably more flesh collapse occurred in apples stored at 32-34° F. with a humidity of 50 per cent than in those held at higher temperatures and higher humidities. Varietal differences also were important in this connection. Similar results were obtained at the Iowa Experiment Station with reference to breakdown and soft scald of apples.

Several of the experiment stations in the northwestern States are finding a considerable variation in the vitamin potency of potatoes stored under different conditions. It appears that both temperature and humidity are important factors in this connection. In addition some of the stations in the apple growing regions are raising questions regarding the vitamin potency of apples stored over different periods under different conditions. Apparently these studies have not as yet been sufficiently controlled to permit a complete correlation of all the factors involved, owing partially, at least, to lack of engineering participation. However, they open an important field of investigation relating to storage requirements which bears directly on the development of the engineering design of apple and potato storages.

Enough data have been secured to suggest the possibility, and in some cases the probability, that a storage which is suitable for one fruit or vegetable product may be entirely inadequate to meet the storage needs of another product, and may even be harmful. It is also evident that some apparently successful storages are harmful to the quality of certain fruits and vegetables. Very evidently the situation needs clarification with reference to the storage requirements of each individual fruit and vegetable commodity.

This would suggest therefore that coordinated studies of the pathological, physiological, nutritional and engineering factors involved in the economic storage of important fruits and vegetables, which will establish the storage requirements of each product and result in the development of engineering principles to adequately meet those requirements, may be worth while.

A study of somewhat this general character with reference to apples was recently undertaken at the Massachusetts Station, and the Indiana Station has been working along this general line with apples for some time. At the latter station certain principles relating to the proper use of air-cooled storages for apples have already been established. It has been found that medium-sized fruit stands up better in such storage than large overgrown fruit and that ventilated bushel crates make the most desirable storage containers.

The work at the Georgia Agricultural College on the control of heat and ventilation in sweet potato storages may also be cited as an obvious effort to develop conditions which will meet the requirements for the proper storage of sweet potatoes. The finding, for example, that the shortening of draft ducts to the minimum gives most effective evaporation and that the admission of large amounts of unheated air is effective in causing evaporation, both being conducive to fuel economy, is significant as a contribution to both the technique and economy of the process. The most uniform temperatures are obtained with distributed heat, and uniformity of temperature is accompanied by uniform relative humidity. It has been found that the dynamic forces in the natural draft system of ventilation are so slight that their effective utilization requires a nicety of balance in the various factors of storage house design. This points to the necessity of establishing under controlled conditions the principles of good ventilation performance before accepting the results of draft, fuel, and other observations as reliable for designing purposes. The interrelation of certain factors is such that reliable data cannot be obtained by isolated uncontrolled studies of service structures.

MISCELLANEOUS FARM STRUCTURES

Some work was done on miscellaneous farm structures during the year including ice houses, silos, dwellings, and the like. For example, the trench silo investigations at the North Dakota Experiment Station indicated that whole bundle corn can be stored successfully in trench silos and is preserved satisfactorily through the summer season. It was found that in a drought year a trench silo large enough to hold several years' feed supply was successful in providing silage when no other feed was available.

The Iowa Experiment Station found that the ice house with the ice above the refrigeration has much to commend it on account of the small amount of labor required. With this type of ice house the entire ice storage is built over a permanent refrigerator often connected directly to the house basement. Thus the refrigerator is kept cool, the labor of icing is eliminated, and unusual efficiency is obtained in ice consumption.

The above typical instances are cited to show how the requirements advanced by subject-matter departments in agriculture and home economics are being considered by agricultural engineers in some quarters and are being solved effectively and along definite cost-saving lines.

MATERIALS OF CONSTRUCTION

Considerable work was done on materials of construction during the year by several different agencies, much of which is significant from the standpoint of farm structures. As usual much of a generally applicable nature was found out about cement concrete, but mention here will be confined to only a few special instances.

The California and North Dakota Experiment Stations continued the studies of rammed earth construction. The former station found that heavy clay soils, particularly adobe and gumbo are not suitable for earth wall building unless mixed with sand or some lighter soil to counteract their tendency to excessive shrinkage. The latter station found that wedge-shaped rammers gave the most uniform wall, and the addition of sand up to 25 per cent greatly reduced the checking of blocks when drying. About 12 per cent of moisture in the soil formed a good consistency for packing, and the use of thin layers for tamping in the form resulted in a more uniform wall than when thick layers were used. The Porto Rico Insular Experiment Station found that adobe bricks with straw binder may be used for farm buildings in the drier parts of the island and rammed earth may be used for walls of farm buildings where the rainfall is more abundant.

The Porto Rico Station also found that tosca, a soft limestone coral deposit, when mixed in various proportions with cement, set quickly and hardened sufficiently for use in the walls of farm buildings. A mixture as lean as 20 parts tosca to 1 part cement was satisfactory in this respect and a 10 to 1 mixture was found by test to possess two-thirds the hardness of concrete.

Fire resistance in farm building construction is becoming increasingly important. It is interesting in this connection to note that the Department of Science and Industrial Research of Great Britain reported that fire-resistant cement may be made by the addition of various substances to the cement, the most suitable of these being certain varieties of clinker and baked clay. Spent shale and granulated slag also gave promising results. Such special cement can be used with fine aggregates.

The U. S. Bureau of Standards has been studying the fire resistance of hollow load-bearing wall tile and has found that the effect of fire exposure on individual tile units varies with the type of clay used, hardness of burning, and the design of the unit. With reference to the last feature double outside shells improved the fire resistance of all but very dense tile by confining the cracking mainly to an outer thin shell. Increased shell thickness also decreased fire effects as did also fillets of up to one-quarter inch radius at the junctions of shells and webs.

The protection of wood timbers, used in farm structures, against decay is also an important economy measure. Considerable evidence has been reported during the year from various sources which indicates that paint coatings, for example, continue to protect wood adequately against weathering only so long as they maintain a reasonable degree of moisture excluding efficiency. It naturally follows that coatings having a moisture excluding efficiency still higher than the traditional house paints afford materially greater protection against wood weathering. In this connection coatings made up of a priming coat of aluminum paint covered by ordinary house paint have been found to be highly impermeable to moisture, are durable, and are especially effective in preventing wood weathering.

The U. S. Forest Service has developed a technique for measuring the degree of protection afforded by paint coatings against the weathering of wood and the change in their protective power as the coatings themselves deteriorate during exposure. The durability of paints as protective coatings can be measured by observing their effectiveness in retarding the absorption of moisture from saturated air by painted wood panels at intervals during the exposure of the panels to the weather. It appears that neither the time of initial chalking nor of initial exposure of wood through coating disintegration can be relied upon as a general indication of the durability of the effectiveness of a coating. During the early part of the life history of an initially adequate protective coating the amount of moisture absorbed by coated wood panels is a characteristic of the coating rather than of the wood. During the latter part of the life history of the coating the influence of the wood becomes noticeable. In test fence results, for example, indications of the deterioration in moisture excluding effectiveness of the coatings were given by the obvious beginning of wood weathering under coatings that still remained intact.

Tests made in Russia of low and high temperature coal tar creosotes and mercuric chlorid as wood preservatives showed that the low temperature creosote on the whole fulfills the requirements of permanency comparatively well, it being only slightly inferior to the high temperature creosote as to constancy of toxicity. It leached out of wood a little more than the high temperature material but was superior in waterproofing quality and had about the same penetration. However, neither material protected wood against moisture absorption to such an extent as to prevent the growth of fungi in wood in contact with a constantly wet medium.

More or less bearing out the above in a practical manner the Arkansas Experiment Station reported that cured native oak posts, given a 24-hour butt treatment in hot and cold bath creosote failed 3.1 per cent at five years, 16.8 per cent at six years and 28.06 per cent at seven years. At the end of two years small treated post specimens showed slight fungous growth and termite action while untreated checks showed 7.7 per cent complete failure and about 33 per cent some decay or termite damage.

The Pennsylvania Experiment Station found that after 20 years no appreciable difference could be noticed in the lasting qualities of western red cedar, redwood, and chestnut shingles, and creosoted Pennsylvania pitch pine, loblolly pine, and chestnut shingles. Creosoted pitch pine was found to warp and twist excessively, while the creosoted loblolly pine showed all the physical properties essential for a good shingle. These and the results noted above would seem to suggest therefore that the use of preservative treatments for timbers should be based primarily on a knowledge of the characteristics of the wood varieties concerned.

With reference to the waterproofing of masonry structures the University of Minnesota reported that of 14 concrete waterproofing materials tested, 13 caused a marked reduction in the strength of some concrete mixes, and their effectiveness as waterproofing agents varied widely. It appeared that better results could be obtained by using richer cement mixtures with a low water-cement ratio than by the use of integral waterproofing compounds.

With regard to new types of construction the finding at the Missouri Engineering Experiment Station that slabs and beams of reinforced brickwork are technically practicable under American building conditions is worthy of mention. It appears that such slabs and beams react in a manner practically identical with the reactions of reinforced concrete. It was found, however, that shearing stresses in beams are not so well resisted by brickwork as by concrete and that no important beam should be without at least light stirrups. Careful and accurate control of the moisture content of the brick was also found to be very important.

It is thus evident that much is yet to be learned regarding materials of construction with the idea of maintaining or improving the quality and increasing the ultimate economy.

CONCLUSION

The above is not a complete review of the work in or related to farm structures during the year. Work on other branches of the subject has been reported which might be mentioned, such for example as the house heating research at the Illinois Engineering Experiment Station, the sewage disposal work at the Illinois, Montana, and New Jersey Experiment Stations, the refrigerator insulation work at the University of North Carolina, and the domestic oil heating work by the American Oil Burner Association.

However, the typical examples mentioned are sufficient to suggest that a rather extensive field for research in farm structures lies in the known agricultural problems of each State. A first-hand study of the programs of agricultural research at a majority of the agricultural experiment stations suggests, in fact, that the primary need for engineering participation in structures research arises in most cases from very definite agricultural problems. It seems important, therefore, that a concerted effort be made to clarify and define the field of research in farm structures as has been done recently in the field of mechanical farm equipment. The purpose should be to bring about an effective coordination of the efforts of agricultural engineers with those of subject-matter specialists in agriculture in the study of specific structures problems.